THE OCCURRENCE OF GROUND WATER IN THE ALAMOGORDO-TULAROSA AREA OF THE OTERO SOIL CONSERVATION DISTRICT NEW MEXICO

By
TOM O. MEEKS, Geologist

REGIONAL BULLETIN III
GEOLOGICAL SERIES 2
MARCH 1950

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
H. H. BENNETT, CHIEF
SOUTHWEST REGION CYRIL LUKER, DIRECTOR

M-199

OTHER REGIONAL BULLETINS OF THE GEOLOGICAL SERIES

Bulletin No.	Title and Author	Date
109	The Occurrence of Ground-water in the Tijeras Soil Conservation District, Bernalillo County, New Mexico; Tom O. Meeks	April 1949

Bulletins of the Geological Series may be obtained by writing to the Regional office of Education and Information or the Regional Water Conservation Division, Soil Conservation Service, Box 1348, Albuquerque, New Mexico.

CONTENTS

Contents (continued)

THE OCCURRENCE OF GROUND WATER IN THE ALAMOGORDO-TULAROSA AREA OF THE OTERO SOIL CONSERVATION DISTRICT IN NEW MEXICO

By

Tom O. Meeks

ABSTRACT

Ground water occurs in the Alamogordo-Tularosa area in the Tertiary and Quaternary alluvium which fills the Tularosa Basin.

Areas which have proved to contain a sufficient quantity of ground water for irrigation exist in the vicinity of Alamogordo and Tularosa with the most favorable areas lying west of the U.S. Highway 54. Both the quantity and quality of water vary widely within short lateral distances. Most of the water is under small hydrostatic pressure and rises a few feet above the aquifers. In the areas farther west a few flowing wells have been developed.

Quality of ground water throughout the area is of prime importance. Most of the waters of the area may be classed as poor to unsatisfactory for human consumption, and much of it is classed as injurious to unsatisfactory for irrigation.

In the Tularosa area, depths to water range from 48 feet to 170 feet. Pumping lifts range from 80 feet to 190 feet. In some instances these pumping lifts may prove to be excessive for profitable irrigation.

INTRODUCTION

Purpose and Scope of the Investigation

The Otero Soil Conservation District, U.S. Farmers Home Administration, and Otero County U.S.D.A. Council have requested information on the availability and quality of ground-water supplies, which is needed in their operations in this area. A detailed investigation of the area was made by the U. S. Geological Survey and published in 1915.

This reconnaissance was made to supplement that report and to provide the above agencies with current information to serve until more detailed and complete data are available. The purpose of the investigation is to summarize all available ground-water information and to interpret it for use in agriculture.

A considerable amount of information on wells and quality of water has been taken from U. S. Geological Survey, Water Supply Paper 343. Some wells listed in that report could not be found in the field and many of them have been abandoned or replaced by newer wells.

Reported water levels were used for a few of the recent wells where it was not possible to measure them. Meinzer's (6) measurements of 1911 were used for many locations, and other measurements were made by the writer.

Well elevations reported by Meinzer (6) and some furnished by the Engineering Department of Holloman Air Base are used. Adjusted aneroid barometer measurement was used when no other elevation was available.

Well locations were plotted on a base map of the Otero Soil Conservation District on a scale of one-half inch equals one mile. In the interest of clarity many wells in the more congested areas are not shown on the map.

Location and Extent of the Area

The area covered by this report lies along the eastern margin of the Tularosa basin in southern New Mexico. It extends southward from the northern boundary of Township 12 South to the southern boundary of Township 18 South. Laterally the area extends from approximately the western face of the Sacramento mountains westward to the First Guide Meridian East. The area includes approximately 545 square miles.

Previous Investigations

A comprehensive investigation of ground water in the Tularosa basin was made by Meinzer and Hare (6) in 1911 and published in U. S. Geological Survey Water Supply Paper 343, 1915. Powell and Staley made an investigation in 1928 under the auspices of the State Engineer of New Mexico, and published their findings in the eighth biennial report of the State Engineer.

In 1945 Theis (10) made a brief investigation of the Alamogordo water supply and his report was supplemented by Murray (7) in 1947.

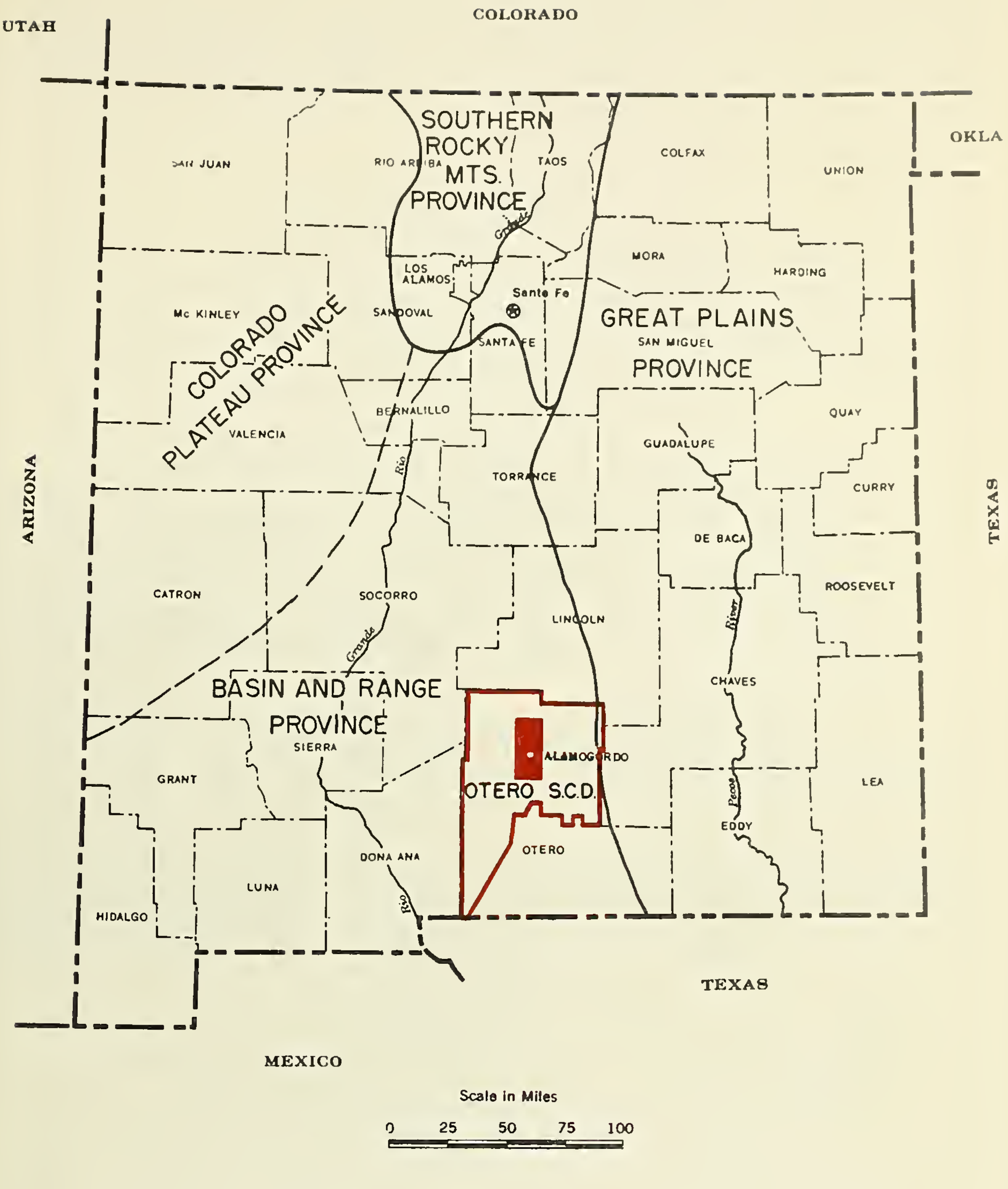


FIGURE I. INDEX MAP OF NEW MEXICO

Showing major physiographic divisions (after Fenneman) and area covered by this paper (solid red). The Otero Soil Conservation District is shown by heavy red lines.

M-199-1

CLIMATE AND PHYSIOGRAPHY

Climate and Vegetation

The climate of the area is characteristic of the arid south-west. In both winter and summer the days are generally warm and the nights cool.

The average annual precipitation ranges from 9 inches in the middle of the basin to about 25 inches near the crest of the Sacramento mountains. Most of the precipitation at the lower elevations occurs during the months of July and August when torrential storms are frequent.

The vegetation of the valley is typical of the desert with creosote bush, mesquite and chamisa dominating. The surface of most of the area has been largely denuded of grass, leaving bare soil exposed between the clumps of mesquite and creosote. Sacaton is abundant locally in swales, in borrow pits along the highway, and near the western margin of the area. Salt grass is abundant in the valleys and lowlands in the western part of the area where the water table is close to the surface.

Physiography and Drainage

The Alamogordo-Tularosa area is a part of the Tularosa basin which lies within the Sacramento section of the basin and range province. The rocks of the Sacramento mountains are downfaulted to the west and lie beneath a great accumulation of sediments deposited in geologically recent time. The surface of the basin was formed by the deposition of sediments by wind and water. This area includes the eastern margin of an elongated structural depression, the surface features of which consist of steeply sloping sides and a large interior area whose inclination is almost imperceptible.

The marginal slopes have been built by floods that periodically issue from the canyons of the Sacramento mountains to the east. The mountain slopes facing the basin are usually short and steep. Near Alamogordo the descent from the mountains to the desert is very abrupt, but north of Alamogordo, La Luz, and Fresnal Creeks, Tularosa River, Rinconada Creek, and Three Rivers have built more gently sloping fans.

The flatness of the extensive desert plain to the west suggests that the region was for a long time submerged, and was built up by deposition of sediment in a large body of standing water. Sink holes are common in parts of the desert plain underlain by recently deposited gypsum. They occur most commonly along the margins of arroyos and range in size from tiny openings to sinks as much as 10 feet in diameter. The gently undulating topography with its shallow undrained depressions is probably due primarily to subsidence although some of the depressions may be due at least in part to wind action.

Erosion is active in the area and numerous large arroyos spill their flood water and debris intermittently on the relatively flat land near the western margin of the area.

GEOLOGY

This area includes a part of the Tularosa Basin which is bounded on the west by the faulted east side of the San Andres Mountains and on the east by the similarly faulted western flank of the Sacramento range. The general structure underlying the alluvium was considered by Darton (3) p. 217, to be synclinal.

The portion of the area covered by this report includes the alluvial fan and mid slope area, and a portion of the interior basin. The upper part of these valley fill deposits is of Quaternary age and although the age of the deeper deposits is not known, the filling of the basin must have required a long time. It is probable that the deeper sediments are of Tertiary age.

The thickness of the unconsolidated material is not known, but it probably exceeds 1,000 feet throughout most of the area. A well drilled west of Alamogordo by the railroad company reached a depth of 1,004 feet without reaching the base of the valley fill. A test well drilled near Valmont in 1910 reached a depth of 1,800 feet without going through the unconsolidated material. Two wells drilled near Twin Buttes are reported to have encountered bed rock at 900 feet. A well at Temporal penetrated 800 feet of fill material, and a deep test drilled in Sec. 34, Township 13 South, Range 8 west, shows at least 1,100 feet of alluvial fill.

An irrigation well drilled by R. D. Champion just north of Tularosa about 1947 was drilled to 1,440 feet. This well penetrated approximately 720 feet of alluvium before reaching solid rock.

The surface exposures and well logs show that the valley fill in this area is composed mainly of red clay and sandy clay with interspersed lenses of sand and gravel. Near the mountains the material is coarser with an abundance of coarse gravel and boulders present on the surface, and in lenses within the clay. Most of the sand and gravel layers or lenses also contain a considerable amount of clayey material.

The beds of clay, sand, and gravel are principally stream deposits but near the western margins of the area they are in part lake deposits and may include some ancient dune sands. Caliche layers underlie most of the areas and in many wells the second water-bearing bed is reported to occur immediately below a limestone or caliche layer. An examination of well cuttings shows that some layers which had been reported by drillers as hard limestone are actually a conglomerate of limestone pebbles cemented with lime.

OCCURRENCE OF GROUND WATER

General Principles

Ground water is the water in the zone of saturation beneath the land surface of the earth. It exists in numerous voids or interstices in the material it occupies, and is the source of supply for wells and springs. When the water is confined by an overlying impervious stratum and is under pressure it is said to be confined water or artesian water. Unconfined ground water is said to be under water table conditions. The water table may be defined as the upper surface of the zone of saturation. Under water table conditions the surface of the water in a well generally stands at the water table.

The water table is not a level surface but an irregularly sloping surface. Irregularities may be caused by differences in thickness, differences in permeability of water-bearing formation or by unequal additions or withdrawals of ground water. The movement of water is in general in the direction of the greatest slope of the water table. The rate of movement, assuming a uniform cross sectional area and uniform permeability of the aquifer, is proportional to

the hydraulic gradient and the permeability of the water-bearing material. Ground-water movement ranges in velocity from a few feet per year to a few hundred feet per year.

All ground water of economic importance is moving from a place of recharge to a place of discharge. This movement may have been going on for thousands of years. In more recent time the rate of discharge from the aquifer has been equal to the rate of input into it. Climatic fluctuations may cause small and temporary variations in water levels but during a climatic cycle the intake and discharge balance. Under natural conditions aquifers are in a state of approximate dynamic equilibrium. When wells are pumped a new discharge is superimposed upon a previously stable system. This new discharge must be balanced by an increase in recharge to the aquifer, a decrease in the natural discharge of the aquifer, a loss of storage in the aquifer, or by a combination of these.

Ground Water Recharge and Discharge

Ground-Water Recharge Areas

Four ground-water recharge areas may be roughly delineated. They are:

- The Western slopes of the Sacramento mountains.
- The alluvial fans and colluvial deposits adjacent to the mountains.
- The middle zone of stream built slopes.
- The interior plain.

The Sacramento mountain area. -- The mountains receive more precipitation than other parts of the area and are the only areas which give rise to permanent streams. The numerous springs which are the source of water for the permanent streams probably contribute a considerable amount of ground water to the basin through percolation into the bottoms of the arroyos. Most of the flood waters are also contributed by the western slopes of the mountains.

Alluvial fans and colluvial deposits. -- The upper parts of the debris slopes adjacent to the mountains are more permeable than the lower lying areas of the basins, and allow ready downward percolation. The streams and flood waters discharged

from the mountains generally cross these deposits in channels, but in some instances they spread over the slopes. In either case they lose much water which percolates downward to the zone of saturation and replenishes the ground-water supply. A portion of the rain water which falls on the slopes also contributes to the underground water supply.

Middle zone of stream built slopes. -- The middle zone of the stream built slopes lies generally in the vicinity of and on both sides of U. S. Highway 54. This zone is characterized by sparse vegetation, mostly creosote bush, and mesquite, which offers little hinderance to runoff from the area. The soil is predominantly clay, and silt with lenses of sand, and gravel. The relative impermeability of the soil, and the rapid runoff prevents much water being absorbed by the soil. Most of the rain which falls on the area moves off as surface discharge and except in the gravel bottomed arroyos which cross the zone, the amount of water contributed to the underground supply by rainfall is probably negligible.

In the vicinity of Alamogordo and Tularosa most of the irrigated land is included within this zone, and an appreciable amount of water may be contributed by downward percolation or irrigation water.

Improved vegetative conditions on the western slopes of the mountains, the alluvial fans, and the stream built slopes will contribute to increased ground-water recharge. Research by the Soil Conservation Service in California has demonstrated that much more water is absorbed when flood water is clear than when it carries considerable sediment. After a few hours run of sediment-laden water, the intake area becomes partially sealed and the rate of water intake drops sharply. If drainage areas above the major intake areas are improved so the flood waters carry less sediment, a larger portion of these flood waters will sink into the ground and replenish the underground reservoir.

The Interior Plain. -- The plains area has little runoff although it has an average rainfall of about 9 inches and receives considerable runoff from the higher areas. The alkali deposits of the plains suggest that only small amounts of water percolate

downward to the water table. The only appreciable contribution to the ground-water supply is from flood waters which run into the many sink holes which have developed in the area.

Most of the ground water found under the interior plains area is too high in salt content for irrigation or domestic use and much of the soil is not suitable for cropland due to the high concentration of salts. Most of this area is now closed to civilian use and any ground-water supplies of the area may be considered as not available for irrigation use at the present time.

Ground-Water Discharge.

With the exception of seasonal variations in storage due to fluctuation of the water table, the ground water discharged is approximately equal to the annual recharge, and an estimate of either gives an estimate of the available annual supply. However it may not always be desirable to limit withdrawal to either natural recharge or natural discharge.

Ground-water resources differ from other underground resources in that they are constantly being replenished. The conservation of ground-water supplies does not necessarily entail the curtailment of use but rather the development of the maximum amount available, which is balanced by the annual replenishment. The annual replenishment to the ground-water supply of Tularosa Basin occurs over a large tributary area. Only a small portion of this replenishment may be available to the wells in areas covered by this report.

Water in the alluvium of the area is probably lost principally to the atmosphere through evaporation and transpiration of plants. Some, especially in the southern part of the basin, is lost by underground seepage to other areas, and some is probably lost into the underlying formations. Return to the atmosphere occurs where the zone of saturation reaches the land surface and the water flows out as springs, and where this zone is near enough to the surface so that the water rises to the surface by capillarity, or is taken up and transpired by plants. Observations by Meinzer (6) p. 109, indicated that the height to which water is lifted by capillarity in the lower part of the Tularosa Basin is about 8 feet. The level of the zone of saturation is maintained by new supplies that are constantly

being added to the underground reservoir and moving to the areas of ground-water discharge. If these new supplies are reduced or sufficient artificial discharge is imposed, the water-table will eventually be drawn down to a level at which natural discharge will diminish or ultimately cease. If water levels are drawn down so that the area of influence reaches the area of discharge it will probably cause salty water to migrate eastward and contaminate the existing wells.

Most of the area of discharge is within the White Sands Proving Ground or the Holloman Air Base. Meinzer (6) p. 193, estimated the barren zone which is destitute of vegetation to be 150 square miles and the area of alkali vegetation, principally salt grass to be about 36 square miles.

Meinzer (6) p. 109, assuming an average rate of evaporation of one foot per year and an area of evaporation of 175 square miles for the Tularosa Basin, estimated that about 110,000 acre-feet of water per year is returned to the atmosphere through evaporation. That portion of the ground water which seeps to the lower areas where soil conditions and quality of water are unsuited for irrigation cannot be recovered for use on the better lands higher up except by intercepting it before it reaches the area of discharge.

The Water Table

As previously stated, all ground water is moving from a place of recharge to a place of discharge. The water surface is seldom level although it has much more gentle slopes and less pronounced irregularities than the land surface. In general both the land surface and the water table slope from the mountains toward the low central area of the basin occupied by the alkali flats. As the land surface is steeper than that of the water table they gradually approach each other. Near the mountains the depth to water generally exceeds 100 feet but it decreases toward the low western area where it nearly coincides with the land surface.

Irregularities in the water surface are pronounced in the vicinity of Alamogordo and Tularosa. The water table slopes to the north, west, and south from the high areas near Alamogordo and Tularosa. South of Alamogordo and west of U. S. Highway 54 the water table slopes to the south at the rate of about 17 feet per mile. North of Alamogordo the

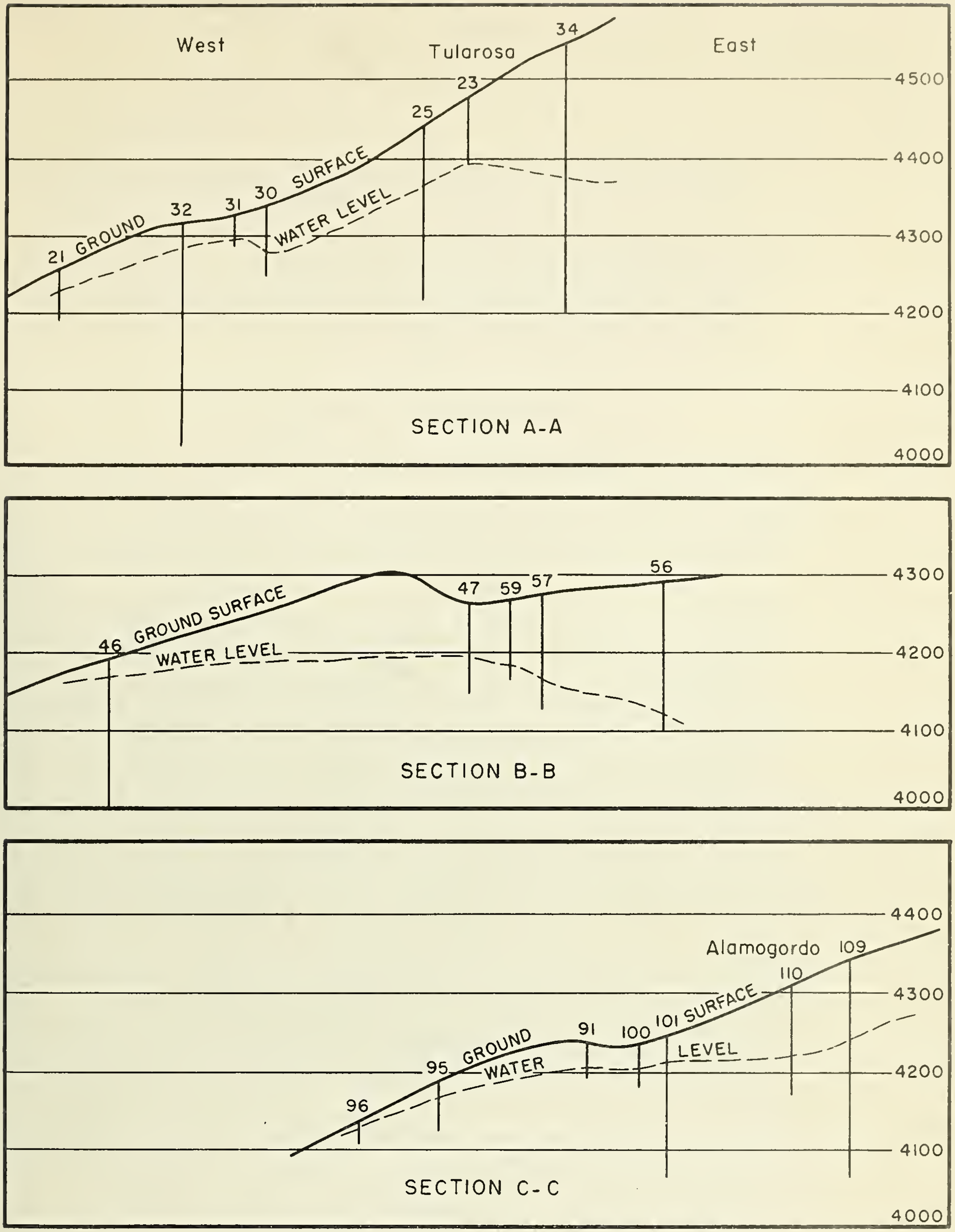


FIGURE 2. SECTIONS SHOWING DEPTH OF WELLS AND GROUND WATER LEVELS.

(Location of sections shown on map)

M-199-2

water table slopes to the west as much as 50 feet to mile, gradually decreasing toward the central part of the basin.

Meinzer (6) shows the water table in the Tularosa Basin forming an asymmetric trough with its axis near the west side and a gentle slope toward the south. Throughout much of the alkali flats area the slope is less than 5 feet to the mile.

GROUND WATER SUPPLIES

Ground water is used in this area for live stock, domestic use, public supplies, and irrigation. Most of the water found within the area is suitable for stock use but water from many wells contains excessive amounts of dissolved minerals for human consumption.

During recent years the need for additional supplies of water for municipal use and to supply the needs of the air base has become increasingly important. The town of Alamogordo and Holloman Air Base have cooperated in attempting to find satisfactory water supplies. Two test wells 501 and 647 feet deep were drilled near Alamogordo without success and nine test wells ranging from 126 to 570 feet deep were drilled on the Boles farm south of Alamogordo. Three of the wells on the Boles farm are now supplying water for the air base and at least two others can probably be developed if the need arises. Water from these wells is very hard but is low in chlorides and is suitable for drinking and other use.

There has been increased interest in development of irrigation wells in the area during the past few years. At least 25 wells have been drilled for irrigation, and three drillers are presently engaged in drilling wells for this purpose. In addition, numerous wells are used to irrigate small garden plots throughout the area.

Most of the irrigation wells range in depth from 150 to 250 feet and only four exceed 300 feet in depth. One well drilled by R. D. Champion just north of Tularosa is reported to be approximately 1,440 feet deep. This well penetrated solid rock and reportedly encountered a large quantity of water at depths between 1100 and 1200 feet. The level to which the water rose from this depth is not known but water level in the well is 156 feet below the ground surface.

The yield of wells varies from 100 gallons per minute to 1,200 gallons per minute. The wells a short distance west of Alamogordo have obtained the greatest yields, and are generally somewhat shallower than those near Tularosa. One test well about two miles east of Valmont was drilled to a depth of 250 feet without finding sufficient water for irrigation.

Most of the irrigation wells have been drilled in areas where surface water is available for irrigation at least part of the season. Where pumping lifts are high these wells should be used as supplemental supplies rather than as the main source of irrigation water.

Alamogordo Area

The depth to the static water level in wells of the Alamogordo area ranges from 27 feet below the ground surface in the Lee wells just west of Alamogordo to 210 feet in the town of Alamogordo test well No. 2 east of town. Depth to the first water-bearing strata averages about 35 feet in the area west of Alamogordo, the depth to the aquifer increasing toward the east. All of the water is under some hydrostatic head, and rises from 8 feet to as much as 85 feet above the aquifers which supply it.

Tularosa Area

Depth to water in irrigation wells in the vicinity of Tularosa range from 48 feet to 170 feet. The shallower water levels occur in the west and southwest portions of the area. The depth to water increases toward the east. The water-bearing strata generally occur at greater depths than in the Alamogordo area. In general the principle water-bearing strata occur within the upper 250 feet. Based on present information, there appears little to be gained by drilling beyond this depth. It is reported that the principle water-bearing strata in the 1,400 foot Champion well was found at depths between 1,100 and 1,200 feet in porous limestone. The quantity available from this depth has not been adequately tested by pumping. Although this deep water may be under some confining pressure it is doubtful if it would rise close enough to the surface for profitable pump irrigation. Depth to water in the well is 156 feet but it is possible that some pressure is lost due to leakage around the casing.

Yield of Wells

The reported yields of wells are based on estimates by drillers and are subject to some error although they are considered sufficiently accurate for practical purposes. Yields in the Alamogordo area range from 100 to 1,200 gallons per minute and specific capacities range from 10 to 11.6. The average for five wells in the area is 573 gallons per minute. Yield of wells in the Tularosa area range from 150 to 700 gallons per minute with an average of 445 gallons per minute for 17 wells. Specific capacities range from 4 to 30.6.

The specific capacity, or the gallons produced per foot of drawdown can be calculated. This value furnishes the best figure for comparison of yield from two or more wells. The specific capacity depends upon two factors: the permeability of the aquifer and the frictional resistance at the entrance to the well. The drawdown was not measured for wells in the area but sufficient specific capacities were computed from reported yields and drawdowns to show some comparison. (see Table 2) Specific capacities are generally low with those in the Alamogordo area running somewhat higher than those near Tularosa. The wells near Alamogordo are closer to the mountains and consequently the aquifers may be expected to be more permeable in this area.

There are indications that in some wells a portion of the top water strata has been sealed off by the casing and in some instances perforations may have been clogged by clay during driving of the casing, thereby reducing the yield of the well.

There is considerable interest in acidizing wells in the Tularosa area. Mr. Harvey Frambeau first acidized a well in this area, and reported some increase in yield although only a small amount of acid was used and the top of the well was not sealed, allowing a considerable amount of acid to escape.

The Ramsey well was tested at approximately 165 feet with a reported yield of 150 to 200 gallons per minute. The well was drilled to about 200 feet and acidized. After acidizing, the well was reported to yield 530 gallons per minute.

The Champion well No. 3, Table 1, No. 178, was reported to have been increased from a yield of 90 gallons per minute to 300 gallons per minute by acidizing. On the first pump test

the Kirk Johnson well is reported to have yielded approximately 500 gallons per minute. The well was deepened and additional water strata encountered. In the final pumping test before acidizing the well yielded only about 300 gallons per minute. Mr. Jack Danley reports that after acidizing, this well yielded 600 to 700 gallons per minute. He reports that the acid came up around the outside of the casing. Possibly the greatest increase in yield came from opening up the several water strata and allowing them to flow into the well. Cleaning out of clogged perforations may also account for some increase.

All four wells which have been acidized to date have shown a marked increase in yields and this practice in this area appears to be well worth the additional cost. However, it seems probable, in alluvial deposits, that additional surging and pumping does as much or more than the acid to improve the wells.

Table 2 - Yield of Irrigation Wells

No.	Owner	Reported total Depth	Reported yield G.P.M.	Reported Drawdown (feet)	Specific capacity yield in gal. per min. per ft. of drawdown
			TULAROSA AREA		
6	Shore #1	230	450	80	5.6
7	Shore #2	150	450	110	4.0
9		58	260	8.5	30.6
15	Potter	229	350		
18	Heine	150	700 ±	32	22. Approx.
22	Johnson	303	600 ±	100	6.0
25	Bookout	216	150		
26	Simpson	325	400		
27	"	200	400		
28	"	200	400		
33	Champion	1,440	500		
34	Champion	340	275		
35	Watson	230	650		
38	Clayton		500		
51	Frambeau	225	660		
179	Ramsey	200	530		
178	Champion No. 3	335	300		
			ALAMOGORDO AREA		
63	Moppin				
85	Lee and Stevens	190	400		
93	Lee, Don No. 1	204	1,200	110	10.9
94	" " No. 2	204	700	60	11.6
101	Melton	190	465	46	10.1
104	McNatt	140	120		
110	Fleming	147	250		
116	McNatt	277	100		
			SOUTH OF ALAMOGORDO		
145	Boles No. 10	260	204	120	1.7
180	Taylor Ranch #1	222	283	15	18.8
190	Old Campwell	160	144	12	12.0

DEVELOPMENT OF GROUND WATER

Hydraulics of Water Wells

Separate treatment of the hydraulic characteristics of wells is required depending upon whether the wells draw on unconfined or confined ground water. The former type draws on free ground water below the water table, and the latter upon confined ground water below a relatively impermeable formation. Pumping of the former lowers the water level in the well, extracts water from the immediately adjacent water-bearing material, and produces a cone of water table depression surrounding and tributary to the well. Water outside of the cone of depression moves toward the well to replace the body of ground water which is flowing into the pumped well.

Pumping of confined water reduces pressure in the water-bearing conduit and causes movement of water in the conduit or aquifer toward the well. Reduction of pressure in the conduit is registered by a lowering of the water levels in adjacent non-producing wells during flow from the producing well. The depression in the pressure surface produced by pumping such a well or group of wells is called the cone of pressure relief.

If a well taps both free and confined water or if the confining formation leaks, both extraction of water from the free ground-water body around the well, and pressure relief in the confining aquifer occur. If the well taps several confined water-bearing strata, a composite pressure relief effect is produced in all the aquifers.

When a well is pumped, the water level is depressed in the well and in the formation surrounding the well. The amount of lowering in feet is called the drawdown. The drawdown is roughly proportional to the quantity of water pumped and inversely proportional to the permeability of the aquifer. Hence the drawdown generally is small in wells that obtain water from well-sorted gravel and coarse sand, but may be excessive in wells in less permeable materials that are poorly sorted, and contain fine sand, silt or clay.

When the water table is depressed due to pumping it takes a form similar to that of an inverted cone, called the cone of depression. The well is at the apex and the slope of the

cone is greater nearer the well and becomes less at increased distances from the well, until a point is reached where the drawdown is imperceptible. The distance to this point is called the radius of influence and the circular area included within this radius is called the area of influence of the well. The radius and area of influence are not constant but continue to increase at a diminishing rate with increased length of pumping of the well. The area of influence stops expanding 1) when it reaches an area where ground-water recharge is rejected and thereby permits an amount of water equal to that discharged by the well to be added to the aquifer; or 2) when it reaches an area of ground water discharge and thereby prevents an amount of water equal to that withdrawn by the well from leaving the aquifer. If the discharge of the well is increased, the drawdown at any particular distance is increased, but the radius of influence is not affected.

The drawdown or lowering of the water level during a certain period of pumping can be measured. If the pumping level becomes stationary after a period of pumping, the natural supply of ground water to the cone of depression is equal to the quantity pumped, and information is thereby furnished as to the supply available. The drawdown necessary to produce the water pumped is a direct function of permeability of the water-producing formations. The comparative permeability of aquifers supplying a number of wells can be determined from the drawdown of the respective wells, provided the resistance to water entering the several wells (diameter of the well and number and size of perforations) is approximately equal.

The static level to which the water rises after cessation of pumping can be measured. Over-pumping is indicated if the water does not rise to its original level after pumping stops, and safe yield is indicated if the recovery between periods of pumping is complete. This method can be used to determine the approximate safe yield of a well but water level measurements over long period of time are needed to determine the effects of pumping in a given area.

Development of Wells

The method of development may affect the yield of wells. From the information available it appears that most of the

aquifers are gravels which contain a large amount of fine sand, silt and clay. In many instances much of the overlying material is heavy clay which may partially seal off perforations in the casing during placement, and thus affect a portion of the water-bearing strata.

Many wells in this area might show an increase in yield if additional development were undertaken after the well was drilled. Surging of the well would probably be of considerable benefit in this area and would probably increase initial yields. In wells which have not been surged an increase in yield may be noticed during the growing season when continuous pumping is practiced. If the well obtains water from coarse gravels, heavy initial pumping, sufficient to remove much of the fine material will add to the yield of the well and prolong its useful life. Wells which have been pumped only short periods after drilling and then allowed to stand for a long period of time without further pumping may sand up near the bottom, resulting in materially reduced yields.

The duration of the pumping test will vary with conditions of the well but usually a minimum of 48 hours of continuous pumping is necessary to adequately test the well. At least 30 hours of continuous pumping would be a good practice in this area, and a longer period is desirable.

The increased yields obtained by acidizing wells may be, at least partially due to cleaning clay particles from the perforations, and the surface of the aquifer in contact with the well casing. The enlargement of solution channels in lime-cemented conglomerate, and removal of clay and silt particles from water-bearing sand and gravel probably accounts for some of the increase. Surging of the well and increased length of pumping test might also result in some increase in yield for wells in this area.

Size of Wells

There is considerable misunderstanding concerning the proper size for an irrigation well. The concept that doubling the size of a well will double the yield is erroneous. For example, according to Tolman (13) p. 391, a 12 inch well will produce about 10 to 15 percent more water than a 6 inch well, while a 48 inch well will produce from 20 to 35 percent more than a 12 inch well, all other factors being equal.

The principal factors governing the size of well to be drilled are the quantity of water it is expected to encounter, and the size of pump necessary to pump that amount of water.

The main advantage in large diameter wells other than the size needed for the pump, is the production of sand-free water from the fine sand. The production of sand-free water is directly proportional to the size of the well, all other conditions being equal.

The amount of fine sand brought into a well is a function of the velocity of the water, and with constant production the velocity of inflow is inversely proportional to the diameter of the well. Doubling the size of a well reduces the entrance velocity to one-half and the friction loss to one-quarter. The most important effect of reduction of entrance velocity is the reduction in sand-carrying capacity of the water. There is a certain critical velocity at which sand of any given grain size will be dislodged from its bed and carried into a well under any constant set of conditions. If the size of well and the number of perforations are doubled, all other conditions remaining the same the critical entrance velocity of the sand will be reached only when production of the well is doubled.

QUALITY OF WATER

General Condition

The mineral character of the water in this area is shown in the table of analysis. A large number of analyses were taken from U. S. Geological Survey, Water Supply Paper 343. Other analyses were made by the El Paso and Southwestern Railroad Company, the New Mexico Agricultural Experiment Station, the laboratories of the U. S. Soil Conservation Service located at the New Mexico Agricultural and Mechanical College, and the Regional Soils Laboratory, Albuquerque, N.Mex. Analyses of water from the L.C. Boles wells and several others in the area were furnished by the U. S. Army Corps of Engineers. Analyses of waters from the test wells for the town of Alamogordo were made by private concerns.

The high mineralization of the waters of this area is caused chiefly by dissolved gypsum and common salt, which are derived from the formations through which the ground water has passed.

A study of the analyses does not show any definite trend in quality of water as to location. In general the waters in the eastern portion of the area show a lesser salt content than the waters in the basin to the west, but there are numerous exceptions to this general rule. The shallower waters tend to show a higher salt content than the second or third water strata but this is not always the case. In most wells of the area all waters are allowed to enter the well and even where the top water is cased off some leakage into the well may occur. From available information it appears that the waters from depths of approximately 80 feet to 150 feet are apt to be of the best quality. The shallower and deeper waters generally are of inferior quality. An irrigation well being drilled in Sec. 3, T.16S., R.9E. encountered its first water at 124 feet. An analyses of the water shows 1262 parts per million total salts which is about average for the area between Alamogordo and Tularosa. This salt content is considerably less than is found in most of the waters to the north and south. Most, if not all of the wells in this area obtain water from only the uppermost aquifer.

Analyses of water from a well just west of La Luz shows 2758 parts per million total salts. Only one water strata was encountered in this well, at a depth of approximately 315 feet.

Water for Domestic and Stock Use

Most wells of this area produce water containing more total salts than recommended in standards adopted by the U. S. Public Health Service and the American Water Works Association. However, many wells are used for domestic purposes without apparent ill effects. Probably the best course will be to consult the local public health officer before planning to use any water of doubtful quality for domestic purposes.

According to standards adopted by the U. S. Public Health Service and accepted by the American Water Works Association, the following chemical substances should preferably not occur in excess of the following concentrations: chloride and sulphate should not exceed 250 parts per million. Total solids should not exceed 500 parts per million for water of good chemical quality but 1,000 parts per million is permissible.

Most livestock can apparently tolerate up to 10,000 parts per million of total dissolved solids without injury to the animals. Both sodium chloride and magnesium sulphate can be tolerated. A period of adjustment is usually required for stock to become accustomed to highly mineralized waters, and they do not make the gains on such water that they would with water of better quality.

Irrigation Water Quality

The quality of irrigation water will become increasingly important in this area in future years. The three most important factors are: total salt content, the soluble-sodium percentage, and the boron content.

Since the soil, crop, climate, drainage, and soil management practices each influence the concentration of salt that can be tolerated in irrigation water, it is evident that no simple classification scheme will hold for all cases.

The soluble sodium percentage is important in classifying water for irrigation although it must be considered along with total salt content. If the soluble-sodium-percentage is less than 60 deterioration of soil structure from excess sodium in the soil will not usually occur. Soils which have good structure and permeability may not be adversely affected if the sodium percentage

in the irrigation water is as high as 75, providing the total salt content is low. Many soils, however, become increasingly less permeable, and appreciably more alkaline and less productive if the soluble-sodium-percentage of the irrigation water is above 75. In most of the waters of this area sodium is not present in sufficient quantity to cause waters to be classed as unsatisfactory on the basis of sodium alone. However, the total salt content approaches the upper limits of tolerance throughout much of the area.

In the Pecos Valley, ill effects have not resulted if the sodium percentage was low even though the total salts sometimes ran as high as 3,000 parts per million. In the Alamogordo-Tularosa area it will be highly beneficial and possibly necessary to practice annual leaching of the salts out of the root zone, usually to a depth of about six feet.

In addition to the harmful effects of accumulations of salt in the soil, increases in the amount of water used for irrigation will be necessary. As salt concentration increases in the soil, larger amounts of soil moisture become unavailable to plants, making it necessary to apply larger quantities of irrigation water.

Standards of Water Quality

The following table taken from U.S.D.A.circular No. 703 gives standards for interpreting quality of water for irrigation:

Table 3 - Standards for Irrigation Waters

Water Class	Specific Conductance K x 10^{0}	Total Dissolved Solids parts per million	Percent Sodium
1	100	700	60
2	100 - 300	700 - 2,000	60 - 75
3	over 300	over 2,000	over 75

Class 1 - Excellent to good; suitable for most plants under most conditions.

Class 2 - Good to injurious, probably harmful to the more sensitive plants.

Class 3 - Injurious to unsatisfactory; probably harmful to most crops, and unsatisfactory for all but the most tolerant.

Selection of Salt Tolerant Crops

Because of the high salt content of irrigation water in this area the selection of crops which can produce maximum yields under saline conditions may make the differences between success or failure.

Although the salt tolerance of crops has been studied for many years the investigations have been made under such a variety of conditions that it is difficult to give any accurate, concise list of plants with their salt tolerances.

The following list is taken from a report by the Regional Salinity Laboratory, of the U.S. Department of Agriculture, at Riverside, California (14) and is intended merely as a guide. The county extension agent may have additional information on crop tolerances in this area and he should be consulted for additional information. All fruit trees adapted to this climate are considered to have poor salt tolerance.

I Good Salt Tolerance	II Moderate Salt Tolerance	III Poor Salt Tolerance
	Field and Truck Crops	
Sugar beets	Alfalfa	Peas
Garden beets	Tomatoes	Cabbage
Milo	Asparagus	Potatoes
Kale	Sorghum (grain)	Sweet Potatoes
Cotton	Barley	Green Beans
	Rye	
	Oats	
	Lettuce	
	Cantaloupe	
	Carrots	
	Squash	
	Onions	
	Peppers	
	Wheat	

Forage Crops

Good Salt Tolerance	Moderate Salt Tolerance	Poor Salt Tolerance
Alkali sacaton	White sweet clover	White Dutch clover
Salt Grass	Yellow sweet clover	Alsike clover
Bermuda grass	Perennial Rye grass	Red clover
Western wheat gr.	Strawberry clover	Ladino clover
	Sudan grass	
	Alfalfa	
	Orchard Grass	
	Blue gramma	
	Meadow fescue	
	Reed canary	
	Smooth brome	

On some lands the effect of highly mineralized irrigation water may not be noticeable for several years. In the Alamogordo-Tularosa area some experimentation may be necessary to determine which crops may be the best adapted to existing conditions.

The low water table, the relatively low sodium percentage, and the permeability of some of the soils of the area will probably permit the use of waters which would under some conditions be classed as unsatisfactory for irrigation. Periodic analyses of the soils on several farms of the area will furnish an index of the rapidity of accumulation of salts and will serve as a guide for leaching of soils to prevent excessive salt accumulations.

DRILLERS LOGS OF WELLS

Well No. 5 - Southern Pacific Railroad, Temporal, N.Mex.

	THICKNESS (feet)	DEPTH (feet)
Wash	16	16
Wash - boulders	11	27
Wash	6	33
Gravel	62	95
Sand	7	102
Gravel	21	123
Boulders	12	135
Wash	11	146
Boulders	48	194
Pink Clay	22	216
Sandy Clay	12	228
Boulders	19	247
Conglomerate	36	283
Sandy clay	7	290
Conglomerate	6	296
Conglomerate and Sandy Clay	27	323
Clay and gravel	15	338
Conglomerate	9	347
Sandy clay	59	406
Conglomerate	11	417
Sandy clay	50	467
Conglomerate	16	483
Sandy clay	33	516
Conglomerate	17	533
Clay	12	545
Clay and gravel	16	561
Conglomerate	3	564
Clay	29	593
Conglomerate	2	595
Clay	19	614
Conglomerate	3	617
Clay	5	622
Conglomerate	33	655
Clay	5	660
Conglomerate	27	687
Clay and gravel	13	700
Conglomerate and clay	19	719
Boulders	5	724
Conglomerate and clay	10	734
Clay and gravel	6	740
Conglomerate	10	750
Clay and gravel	17	767
Clay	33	800

DRILLERS LOGS OF WELLS

Well No. 33, R. D. Champion - NE$\frac{1}{4}$ Sec. 19, T14S. R10E

	THICKNESS (feet)	DEPTH (feet)
Gravel, clay and boulders	145	145
Sand and water	15	160
Red clay	40	200
Clay, gravel, sand, water	50	250
Red clay	25	275
Lime rock	20	295
Clay with gravel streaks	255	550
Hard lime rock	20	570
Clay with gravel streaks	150	720
Lime with hard and soft streaks	45	765
Red sandy rock	70	835
Red clay	30	865
Hard lime	25	890
Sand and possible water	20	910
Red clay	45	955
Hard lime	50	1005
Lime	10	1015
Hard lime	45	1060
Red clay	30	1090
Red clay and shale	100	1190
		1250
Porous lime and water	110	1360
Red shale	80	1440

Well No. 51, Harvey Frambeau - SE$\frac{1}{4}$ Sec.7, T.15S. R10E

Fine reddish-brown sand and silt	4	94
Reddish brown silt and sand	4	98
Fine reddish brown sand, water	5	103
Brown silt and fine sand	3	106
Brown silt and fine sand with some small gravel	10	116
Brown silt and fine sand slightly cemented	11	127
Brown silt with fine to coarse sand	10	137
Brown silt and fine to medium sand	9	146
		147
Brown silt with some fine gravel, limy	8	155
Fine sand and some fine gravel in brown)	7	162
silt)		168
Brown, fine to coarse sand and silt, some fine gravel	8	176
Brown, med. to crs. sand, some fn. gravel and silt	8	184
Water 207 to 224		214
Brown silt and sand with coarse gravel	10	224

DRILLERS LOGS OF WELLS

Well No. 106, NM. School for the Blind, Alamogordo

	THICKNESS (feet)	DEPTH (feet)
Soil	5	5
Red sandy clay	35	40
Gravel-water, guppy	2	42
Red sandy clay	38	80
Sand, water	3	83
Red sandy clay	29	112
Gravel, water	1	113
Red sandy clay	3	116
Gravel, water	1	117
Sand	2	119
Clay	1	120
Coarse, water-bearing gravel	8	128

Well No. 107, Southern Pacific Railroad, Alamogordo

Red clay	15	15
Gypsum	5	20
Stratified red clay and clay stone water at fifty feet	70	90
Red clay and gravel	35	125
Lime rock	5	135
Yellow clay and claystone . .	80	215
Red clay	25	240
Sticky red clay	68	308
Red clay	151	459
Yellow clay	10	469
Red clay	6	475
Blue clay	8	483
Yellow clay	8	505
Clay material	449	1004

Well No.140 - L.C.Boles, Air Base #3, S$\frac{1}{2}$ Sec.18, T.17S, R10E.

Sandy loam	4	4
Clay (hardpan)	7	11
Clay with trace of sand . . .	7	18
Clay	24	42
Clay with trace of sand . . .	55	97
Solid rock, blue limestone .	7	104
Coarse sand, large gravel . .	8	112
Clay on shale	14	126

Well No. 142, L. C. Boles, Air Base #4
NE$\frac{1}{4}$, Sec.19,T17S, R10E

	THICKNESS (feet)	DEPTH (feet)
Sandy loam	3	3
Clay with sand	29	42
Clay	42	84
Sandy clay	26	110
Fine sand and small gravel	3	113
Sandy clay	105	218
Find sand	2	220
Sandy clay	95	315

Well No. 144, L.C. Boles, Air Base #7
SW$\frac{1}{4}$, NW$\frac{1}{4}$, Sec.19, T.17S, R10E

Sandy loam	8	8
Clay with large gravel . .	11	19
Clay with gravel	29	48
Sandy Clay	22	70
Shale	4	74
Clay with gravel	50	124
Sandy clay	10	134
Clay	32	166
Gravel	2	168
Clay	10	178
Sand	2	180
Clay with gravel	37	217
Shale	3	220
Clay with gravel	30	250
Shale	3	253

Well No. 145, L. C. Boles, Air Base #10
NW$\frac{1}{4}$, Sec. 19, T.17S, R10E

Sandy loam	9	9
Clay	94	103
Fine sand and gravel, water	9	112
Sandy clay	28	140
Shale	6	146
Clay	19	165
Fine sand, water	9	174
Clay	86	260

Well No. 146, L. C. Boles, Air Base #11
NW$\frac{1}{4}$, Sec. 19, T.17S, R10E.

	THICKNESS (feet)	DEPTH (feet)
Top soil	9	9
Clay	93	102
Water strata	3	105
Clay	35	140
Shale	4	144
Clay	274	418
Gravel	422	4
Clay	148	570

TABLE 1. RECORD OF WELLS

Map No.	Owner	Location: Township South	Location: Range East	Sec	Qtr	Total Depth (Ft)	Static Water Level (Ft)	Yield Gals. per Min.	Draw-down (ft)	Diameter (In)	Use	Year Drilled	Driller
1		12	9	3	NW	300	280*	Weak					
2		12	9	2	SW	400		Dry					
3	Spencer	12	9	18	SW	70	50*				S		
4	Oil Test	13	8	34	SE	3965					S		
5	Southern Pacific	13	9	14	SE	800	190*					05	Mulholland
6	Shore, J. S., #1	13	9	20	NE	230	Flows*	Pump 450	80	10	S-I	48	Goad
7	Shore, J. S., #2	13	9	20	NE	150	10*	450	110	16	I	49	L. Perry
8	Turner	13	9	36	NE	300	200*	20		6	I-S		
9		14	9	8	SW	58	8	260	$8\frac{1}{2}$	6	S		
10		14	9	7	SW	180	18	Small	8		D		
11		14	9	8	SE	56	22	Small			D		
12		14	9	9	NE		10				(Not (Used		
13		14	9	9	SE	40	31				D-I		
14		14	9	10	NW		27				D		
15	Potter, Thomas	14	9	13	NE	229	116	300-400	Small	$8\frac{1}{2}$	I	49	G. Perry
16		14	9	14	NE	116	92	70		9	D-I		
17		14	9	15	NW		42				Not used		
18	Heine, Henry	14	9	15	SW	150	48*	600-800	32	16	I	49	Case
19	Johnson (State well)	14	9	16	NE			700			I		
20		14	9	17	NE		22				Not used		
21		14	9	19	SE		21				Not used		
22	Johnson, K	14	9	24	NE	303	90*	600-700	100	16	I	50	Case
23		14	9	25	NE	80	77				Not used		

S- Stock; D- Domestic; I- Irrigation; P- Public Supply.
*Reported water levels; all others were measured.

TABLE 1. RECORD OF WELLS (Cont.)

Map No.	Owner	Location Township South	Range East	Sec.	Qtr	Total Depth (ft)	Static Water Level (ft)	Yield Gals per min.	Draw-down (ft)	Diameter (In)	Use	Year Drilled	Driller
24		14	9	25	NW		125			Not used			
25	Bookout	14	9	25	NW	216	147*	150	Pumps out	8	I	47	G. Perry
26	Simpson, W.R.	14	9	26	SE	325	100*	400		8	I	48	G. Perry
27	Simpson, D.	14	9	26	SE	200	100*	400		8	I	48	G. Perry
28	Simpson, J.	14	9	26	SE	200	100*	400		8	I	48	G. Perry
29		14	9	27	SE		58						
30		14	9	27	NW		56				D-I		
31	Gordenhire (Purday)	14	9	28	NE	35	29	10			D-I		
32	Gordenhire, Montie	14	9	28	NW	285	30*			10	D-I	19	Purday
33	Champion, R.D. #1	14	10	19	NE	1440	156	500			I	47	G. Perry
34	Champion, R.D. #2	14	10	29	NW	340	170*	275		10	I	46	
35	Watson, Luther	14	10	31	SE	230	69	600-700		16	I	49	Case
36		15	8	1	NE	40	Flows	3		2	S		
37		15	9	1	NE		55				Not used		
38	Clayton, C.V.	15	9	1	NE		58	500			I		
39		15	9	2	--		64				Not used		
40		15	9	3	--		20				S		
41		15	9	6	NE		32				D		
42		15	9	12	SE	34	30				D		
43		15	9	12	SE	60	31			3	Not used		
44		15	9	24	SE	140	85	3			D		
45		15	9	24	SW	64	59				D		
46	Danley, O.	15	9	29	$S\frac{1}{2}$	201	20*	Small			S		
47	Daugherty, M.	15	9	25	SE		60*						
48		15	10	6	NE		75				D-S		
49		15	10	7	NE	81	76				Not used		
50		15	10	7	NW		35						

TABLE 1. RECORD OF WELLS (Continued)

Map No.	Owner	Location Township South	Range East	Sec.	Qtr.	Total Depth	Static Water Level (ft)	Yield Gals. per min.	Draw-down (ft)	Diam-eter (in)	Use	Year Drill-ed	Driller
51	Frambeau, Harvey	15	10	7	SE	225	65*	660	)Not)Meas.	16	I	49	Frambeau
52		15	10	9	SW	125	120*			6	S		
53		15	10	17			134			6	Not used		
54		15	10	18	NW		48						
55		15	10	22	SE	25	21				S	Dug	
56		15	10	28	SW		170			6	Not used		
57	Daugherty, M.	15	10	30	SE		110*				not used		
58	"	15	10	31	NW	138	86*			5	not used		
59	"	15	10	31	NW		81				not used		
60		16	8	11	SE		6				not used		
61	McNatt	16	8	12	SW	50	12*						
62		16	9	2	NW	175					not used		
63	Moppin, Wade	16	9	3	SE		115'4"			12	I	50	McNatt
64		16	9	3	NW		110				not used		
65		16	9	4	NW	100	63	20		7	I		
66		16	9	4	NW	100	63	75		6	I		
67		16	9	5	NE	32	28	3			D		
68		16	9	5	SE		42						
69		16	9	6	SE	17	12				D-S		
70	Daugherty, M.	16	9	6	NW		15				not used		
71	"	16	9	6	N½	212	30*				S	47	McNatt
72		16	9	9	SW		49				D-S		
73	Woffard, Joe	16	9	9	SE	70	80*				S		McNatt
74		16	9	10	SE		82						
75		16	9	12	NE		156				D-S		
76		16	9	13	SE		71						

TABLE 1. RECORD OF WELLS (Continued)

Map No.	Owner	LOCATION Township South	East	Range Sec	Qtr	Total Depth (ft)	Static Water Level (ft)	Yield Gals. per min.	Draw-down (ft)	Diamet-er (In)	Use	Year Drill-ed	Driller
77		16	9	13	NW		98						
78		16	9	14	NW	95	89				D-S		
79		16	9	16	SE		41						
80	Harvey, C. M.	16	9	17	SE		10						
81		16	9	22	SE		47				D-S		
82	Morgan	16	9	23	NW	65	54				D-S		
83	"	16	9	23	NW	160	54	40		9	I		
84		16	9	23	SE		52						
85	Lee and Stevens	16	9	25	NE	190	13	400		8	I		
86	Old Ice Plant	Alamogordo				186		375	19	10	Ind.		
87		16	9	25	NW	60	39				S		
88		16	9	25	NW	50	20			6	Not used		
89		16	9	25	SW	95	33				S		
90		16	9	26	NW		38				Not used		
91		16	9	26	SW	40	30				S		
92		16	9	26	SW	80	24			8	Not used		
93	Lee, Don #1	16	9	26	SE	204	27*	1200	110	12	I	47	
94	Lee, Don #2	16	9	26	SE	204	27*	700	60	10	I	49	McNatt
95		16	9	28	SW		24				Not used		
96		16	9	32	NW		9				Not used		
97	McNatt, Sam	16	9	32	SW	157	14*				S		
98	Harvey	16	9	33	SW	122				2	D-S		
99		16	9	34	SW	67		30			D-I		
100		16	9	35	SE		33				Not used		
101	Melton	16	9	36	NW	190	27*	465	46		I		
102		16	10	7	SE	81	78				D		
103		16	10	7	NE		131						
104	McNatt, James	16	10	7	SE	140	63*	120			I		McNatt
105	Haynes	16	10	17	NE	130	90*				D		

TABLE 1. RECORD OF WELLS (Continued)

Map No.	Owner	South	East	Sec.	Qtr	Total Depth (ft)	Static Water Level	Yield Gals. per min.	Draw-down (ft)	Diame-ter (In)	Use	Year Drill-ed	Driller
106	School for Blind	Alamogordo				128	56*			$8\frac{1}{4}$			
107	Southern Pacific	16	10	19		1004	35*			$8\frac{1}{4}$	Not used	06	Lindholm
108		16	10	20		160				6	Not used		
109		16	10	29	NE	280	100				Not used		
110	Fleming, B.	16	10	29	SW	147	90	250		6	I		
111		16	10	32	SE								
112		16	10	31	-		122				D-S		
113		17	9	1	SE	104	98				D		
114		17	9	1	SW		50				Not used		
115	McNatt	17	9	1	NW	212				8	I		McNatt
116	McNatt	17	9	2	NE	277	35*	100		10	I		McNatt
117		17	9	2	SW	80					D		
118		17	9	3	NE	125	14				D-S		
119		17	9	3	SE	135							
120		17	9	3	NW	65	24	40		7	I		
121	McNatt	17	9	4	SW	130	28*			2	D-S		
122		17	9	5	NE	60	32						
123		17	9	8	NE	137							
124	McNatt	17	9	8	NE	137					S		
125		17	9	9	NW		28			2	S		
126		17	9	10	-	103	31						
127		17	9	11	NW		22						
128		17	9	11	NE		48						
129		17	9	11	SE		48						
130		17	9	13	SE	85	80						

TABLE 1. RECORD OF WELLS (Continued)

Map No.	Owner	LOCATION Township South	Range East	Sec	Qtr	Total Depth (ft.)	Static Water Level (ft.)	Yield Gals. per Min.	Draw-down (ft)	Diameter (in.)	Use	Year Drilled	Driller
131		17	9	23	SW	85	30				D-S		
132		17	9	24	NE	68	65				D-S		
133		17	9	25	SW	45	37	10			S		
134		17	9	26	NE	90	42				S		
135		17	9	26	SW		29				Not Used		
136	City of Alamogordo	17	10	5	NE	501		Dry			Test		
137	Boles, L.C. (Gov't. Well #8)	17	10	18	SW	262		Dry		10	Test	49	
138	" " " #9)	17	10	18	SE	244		170		10	Test	49	
139	" " " #6)	17	10	18	SE	228				10	Test	49	
140	" " " #3)	17	10	18	$S\frac{1}{2}$	126				10	Test	49	
141	" " " #2)	17	10	19	NW		83*	220		10	P	49	
142	" " " #4)	17	10	19	NE	315	85*	140		10	Test	49	
143	" " " #5)	17	10	19	NW	220	72*	170		10	P	49	
144	" " " #7)	17	10	19	NW	253	70*	Very Little		10	Test	49	
145	" " " #10)	17	10	19	NW	260	72*	204	120	10	P	49	
146	" " " #11)	17	10	19	NW	570		30-40		10	Test	49	
147	" " " #1)	17	10	19	NW	162	65*	200		8	Not Used		
148		17	10	31	NE		96				D		
149		17	10	31	SW		82				D		
150	Taylor Ranch #1	17	10	32	NE	222	170*	283	15		I		
151	Twin Battle Well	18	8	5		900	Flows						
152		18	8	7			Flows						
153		18	9	1	NE	70	63				D-I		
154		18	9	1	SE	82	57	14			D-I		
155		18	9	10	SE		34						

TABLE 1. RECORD OF WELLS (Continued)

Map No.	Owner	LOCATION Township South	Range East	Sec	Qtr	Total Depth (ft.)	Static Water Level (ft.)	Yield Gals. per min.	Draw-down (ft.)	Diameter (in.)	Use	Year Drilled	Driller
156		18	9	11	SE	50	36				D		
157		18	9	12	SE	87	58	28			not used		
158		18	9	13	NW		20						
159		18	9	13	SE	103	41	15			D-I		
160		18	9	14	NE	160	38	144	12		I		
161		18	9	14	SW		32				D-S		
162		18	9	23	NE		35			6			
163		18	9	25	NE		24				D		
164		18	9	26	NW	50	30				D-S		
165		18	10	6	SW		55				D		
166		18	10	7	NW		54				S		
167		18	10	7	NE	66	60				D		
168		18	10	8	NW	102	97				D		
169	Ray, C. B.	18	10	18	NE	250	72	100 Appr.			not used	49	Ray
170		18	10	18			41				not used		
171		18	10	19	NW		49			$3\frac{1}{4}$	S		
172		18	10	28	NW	85	58				not used		
173		18	10	28	SE	91	86			18			
174		18	10	29	SW		70			5	not used		
175		18	10	33			84			18			
176		18	10	34	NW	115	100				D		
177	Town of Alamogordo, #2,	Alamogordo				647	210*	60	190 Approx		Test		
178	Champion, R.D. #3	14	10	18	SE	335		300			I	50	L.Perry
179	Ramsey	14	9	25	NW	200	115	530				50	Case
180	Holloman Air Base					110	20*			6	not used	49	
181	Braziel, C.W.	15	10	26	SW	330	315			8	D	50	Braziel
182		16	9	33	$N\frac{1}{2}$		29			$6\frac{1}{2}$	S		
183	Toncroy	14	10	32	NW	294	130*			16	I	49	Case
184	Dunn	16	10	17		136	90*				D		McNatt

TABLE 4. ANALYSES OF WELL WATERS

Quantities Expressed in Parts per Million

No.	Name	LOCATION Township South	Range East	Sec.	Qtr.	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Sulphate (SO_4)	Carbonate (CO_3)	Bicarbonate	Total Solids PPM	Per cent Sodium	Hardness ($CaCO_3$)
10		14	9	7	SW	612	278	722*	807	2794	104		5500	37.0	174
11		14	9	8	SE	383	175	261*	328	1545	104		3201	25.3	174
13		14	9	9	SE	569	179	129*	279	1813	97		3262	11.5	161
16		14	9	14	NE	273	123	173*	199	1044	119		2164	24.0	233
21		14	9	19	SE	306	120	101*	155	949	164		2236	14.9	273
26	Simpson, W.R.					460	136	874	252	2880	0	305	4907	52.8	
28	Simpson, J.E.					434	142	306	287	1728	0	152	3049	28.5	
31		14	9	28	NE	309	129	157*	239	1039	134		2250	20.8	223
36		15	8	1	NW	295	106	141*	217	984	104		2283	20.7	174
40		15	9	3		415	106	149*	229	1347	59		2544	18.0	99
41		15	9	6	NE	327	103	121*	186	1055	89		2204	31.0	149
42		15	9	12	SE	350	127	645*	656	1632	104		3827	50.0	174
44		15	9	24	SE	295	67	423*	479	1028	111		2632	47.6	185
49		15	10	7	NE	426	173	452*	616	1604	134		3624	35.6	223
52		15	10	9	SW	437	96	650*	683	1682	111		4267	48.7	186
58		15	10	31	NW	219	183	41*	417	603	105		1883	6.4	174
67		16	9	5	NE	142	66	174*	168	516	149		1324	37.6	248
69		16	9	6	SE	240	80	158*	244	702	119		1670	27.0	199
75		16	9	12	NE	197	66	107*	186	490	134		1316	23.3	223
78		16	9	14	NW	184	64	121*	186	488	134		1177	26.7	224
79		16	9	16	SE	208	94	248*	266	813	134		1990	37.3	223
80		16	9	17	SE	317	119	277*	412	1071	111		2493	32.9	186
82		16	9	23	NW	131	119	382*	368	870	134		2168	50.4	224
85	Lee & Stevens	16	9	25	NE								8030		2850
86		16	9	25	NE	197	90	176*	270	639	119		1680	30.7	199

TABLE 4. ANALYSES OF WELL WATERS (continued)

No.	Name	LOCATION Township South	Range East	Sec.	Qtr.	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Sulphate (SO_4)	Carbonate (CO_3)	Bicarbonate	Total Solids PPM	Percent Sodium	Hardness ($CaCO_3$)
87		16	9	25	NE	437	219	495*	1072	1250	156		4241	35.1	261
89		16	9	25	SW	642	139	552*	357	2520	150		5540	35.5	250
	Deep Test	16	9	26	NE	598	86	201*	210	1801	54		598	19.1	90
91		16	9	26	SW	407	347	1118*	1179	2745	209		6660	49.8	348
98		16	9	33	SW	215	117	248*	315	916	98		3360	34.6	163
102		16	10	7	SE	111	63	426*	266	876	104		2034	63.3	174
106	Blind School	1				549	216		881	1384		1039	4145		1350
112		16	10	31	NW	83	59	103*	160	363	45		880	33.2	74
113		17	9	1	SE	262	137	233*	221	1194	104		2516	29.4	174
114		17	9	1	SW	426	307	802*	878	2680	179		5660	42.8	299
117		17	9	2	SW	316	149	470*	465	1472	134		3288	42.1	224
119		17	9	3	SE								2584		
121		17	9	4	SW	252	126	331*	510	915	119		2476	38.5	199
122		17	9	5	NE	470	371	1211*	1897	2580	37		7280	49.4	62
130		17	9	13	SE	114	61	36*	55	340	109		821	12.7	183
131		17	9	23	SW	241	120	201*	244	976	105		2140	28.5	174
134		17	9	26	NE	186	119	127*	177	728	134		1680	22.4	224
	Point of Sands	18	7	14	SW	539	335	261*	188	2769	91		4804	17.3	152
140	Boles, L.C. #3	17	10	18	S½	103	46	46	28		279	260	631	17.8	446
141	Boles, L.C. #2	17	10	19	NW	89	38	32	29	208	0	231	532	15.5	378
145	Boles, L.C. #10	17	10	19	NW	122	50		37	323		233	680	12.0	510
147	Boles, L.C. #1	17	10	19	NW	90	37	28	27	192		242	516	13.9	376
153		18	9	1	NE	108	54	83*	100	330	114		788	26.8	190
154		18	9	1	SE	180	107	69*	299	421	108		1468	14.4	180
155		18	9	10	SE	312	290	392*	556	1811	97		3751	30.2	162
156		18	9	11	SE	204	179	286*	321	1183	111		2724	33.3	185
159		18	9	13	SE	216	116	150*	199	827	150		1804	24.3	201

TABLE 4. ANALYSES OF WELL WATERS (continued)

No.	Name	LOCATION Township South	Range East	Sect.	Qtr.	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Sulphate (SO_4)	Carbonate (CO_3)	Bicarbonate	Total Solids PPM	Per cent Sodium	Hardness ($CaCO_3$)
161		18	9	14	SW	156	97	126*	194	558	125		1452	25.8	208
163		18	9	25	NE	126	156	308*	144	1195	106		2277	41.2	178
164		18	9	26	NW	611	304	829*	953	3016	60		6912	39.3	100
167		18	10	7	NE	168	93	209*	104	782	177		1648	36.1	295
172		18	10	28	SE	114	57	43*	67	323	111		752	15.3	186
	Wayne, J. G.	Alamogordo				466	318	667	585	2822	0	183	5041	37.	
111	McMorrey					302	151	197	280	1190		184	2230	23.7	1370
	Walker, Est.					554	250	947	1093	2712	0	128	5684	46.1	
	Jackson	East edge Alamogordo				324	156				0	179	2790		1450
	Ostic	South of Alamogordo				230	128		215	827	0	195	1905		1071
	French	Alamogordo				229	22		175		0	230	1516		871
	Swimming Pool	Alamogordo W.R.R. Tracks				580	280	402	930	1830	0	335	4880	25.	
	Alamogordo Test	Well #2 -Water at 300 ft.				136	68		104	358	0	151	889		640
	" "	" Water Below 300'				88	54		46	362	0	202	655		410
51	Frambeau	15	10	7	SE	421	68	210	338	1113	0	185	2335	27.	
63	Moppin, Wade	16	9	3	SE	204	10	173	182	461		232	1262	40.	
181	Braziel, C.W.	15	10	26	SW	489	61	276	368	1220	0	344	2758	29.	
22	Johnson	14	9	24	NE	462	68	53	367	788	0	256	1994	7	

*Includes sodium and Potassium, analyses from U. S. Geological Survey Water Supply Paper 343.

BIBLIOGRAPHY

1. Bates, Robert L. - The Oil and Gas Resources of New Mexico, 2nd Edition, New Mexico School of Mines Bulletin No.18,1942.

2. Darton, N.H. - Geologic structure of parts of New Mexico U. S. Geological Survey Bulletin 726, 1922.

3. Darton, N.H. - Red Beds and Associated Formations in New Mexico U. S. Geological Survey Bulletin 794, 1928.

4. Fenneman, Nevin M. - Physiography of Western United States, 1931.

5. Magistad,O.C. and Christianson,J.E. - Saline Soils, Their Nature and Management. U.S.Dept.of Agriculture Circular No. 707.

6. Meinzer, O. E. and Hare, R.F., Geology and Water Resources of Tularosa Basin, New Mexico, U.S. Geological Survey, Water Supply Paper No. 343, 1915.

7. Murray, R.C., Note on the possibility of developing ground water for the Alamogordo Army Air Base, April 11, 1947.

8. Powell, W. Carlos and Staley, C.G., - Report on Investigation of the Geology and Water Resources of the Tularosa Basin. Eighth Bienn.Rpt., State Engineer of N.Mex. 1926 to 1928. pp. 193-206.

9. Rohwer, Carl - The Hydraulics of Water Wells. U.S.Department of Agriculture. Soil Conservation Service, Fort Collins, Colo., March, 1947.

10. Theis, C.V. - Notes on Alamogordo Water Supply, Tularosa Basin, May 19, 1945.

11. Theis, C.V. - The source of water derived from wells, Civil Engineering, May 19, 1945.

12. Theis, C.V. - The significance and Nature of the Cone of Depression in Ground-water Bodies. Economic Geology Vol. XXXIII, No. 8, December 1938.

13. Tolman, C.F. - Ground Water. First Edition, 1937.

14. Diagnosis and Improvement of Saline and Alkali Soils, U.S. Regional Salinity Laboratory, Riverside, Calif., July, 1947.

15. Wilcox, L.V. - Explanation and Interpretation of Analyses of Irrigation Waters, U. S. Department of Agriculture Circular 784,May '48.

GLOSSARY OF TERMS

Alluvial Cone. A steeply-sloping body of alluvial material deposited by a stream debouching from an upland into a valley or plain. If the stream has relatively gentle slopes it is called an alluvial fan.

Aquiclude. A formation which, although porous and capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for a well or spring.

Aquifer. A water-bearing formation or structure that transmits water in sufficient quantity to supply pumping wells or springs.

Aquifuge. A rock which contains no interconnected openings and therefore neither absorbs or transmits water.

Area of Influence. The area beneath which water table or pressure-surface contours are modified by pumping.

Area of Depression. The area overlying the cone of pumping depression, or cone of water-table depression.

Artesian Well. A well tapping a confined or artesian aquifer in which the static water level stands above the water table.

Bolson. A topographic basin with centripetal drainage system.

Confined ground water. A body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with overlying ground water except at the intake. Confined water moves in conduits under the pressure due to difference in head between intake and discharge areas of the confined water body.

Drawdown. Lowering of water level caused by pumping. It is measured for a given quantity of water pumped during a specified period, or after the pumping level has become constant.

Ground water. Water in the earth which completely fills the pore spaces of the rocks which it occupies.

Ground-water Decremant. Water taken from the ground-water reservoir by evaporation, transpiration, spring flow, pumping wells and outflow of ground water from underneath the area under consideration

Ground-water Increment. Water added to the ground-water reservoir from all sources.

Hydraulic Gradient. A profile showing the static level of water at all points on the profile.

Perched Ground Water. Ground water occurring in a saturated zone separated from the main body of ground water by impermeable material.

Permeability. The capacity of water-bearing material to transmit water.

Phreatophytes. Plants that habitually send their roots to the capillary fringe and draw on ground water.

Recharge area. The area where recharge to an aquifer occurs.

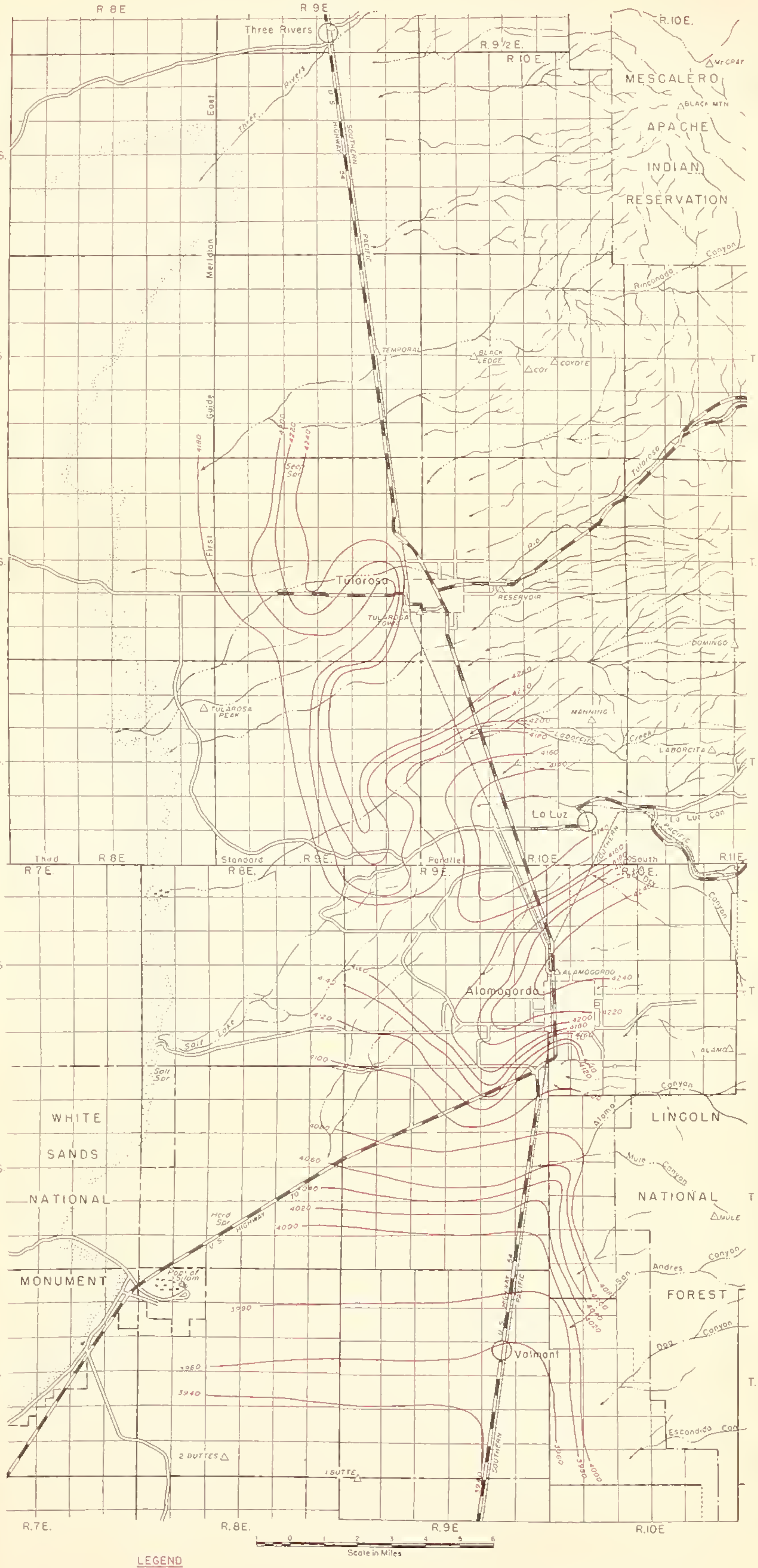
Specific capacity. The number of gallons of water per minute produced by a pumping well per foot of drawdown.

Static Level. The water level in a non-pumping well outside the area of influence of any pumping well.

Subsurface water. All water occurring below the ground surface.

Water Table. In pervious granular material the water table is the upper surface of the body of free water which completely fills all openings in material sufficiently pervious to permit percolation.

Valley fill. Deposits of gravel, sand, silt and clay occurring in broad basins or valleys between mountain ranges.



LEGEND

Contour interval 20 feet

PLATE I
ELEVATION OF THE
GROUND WATER SURFACE

BASE: General Highway Map Otero County, New Mexico

MARCH, 1950

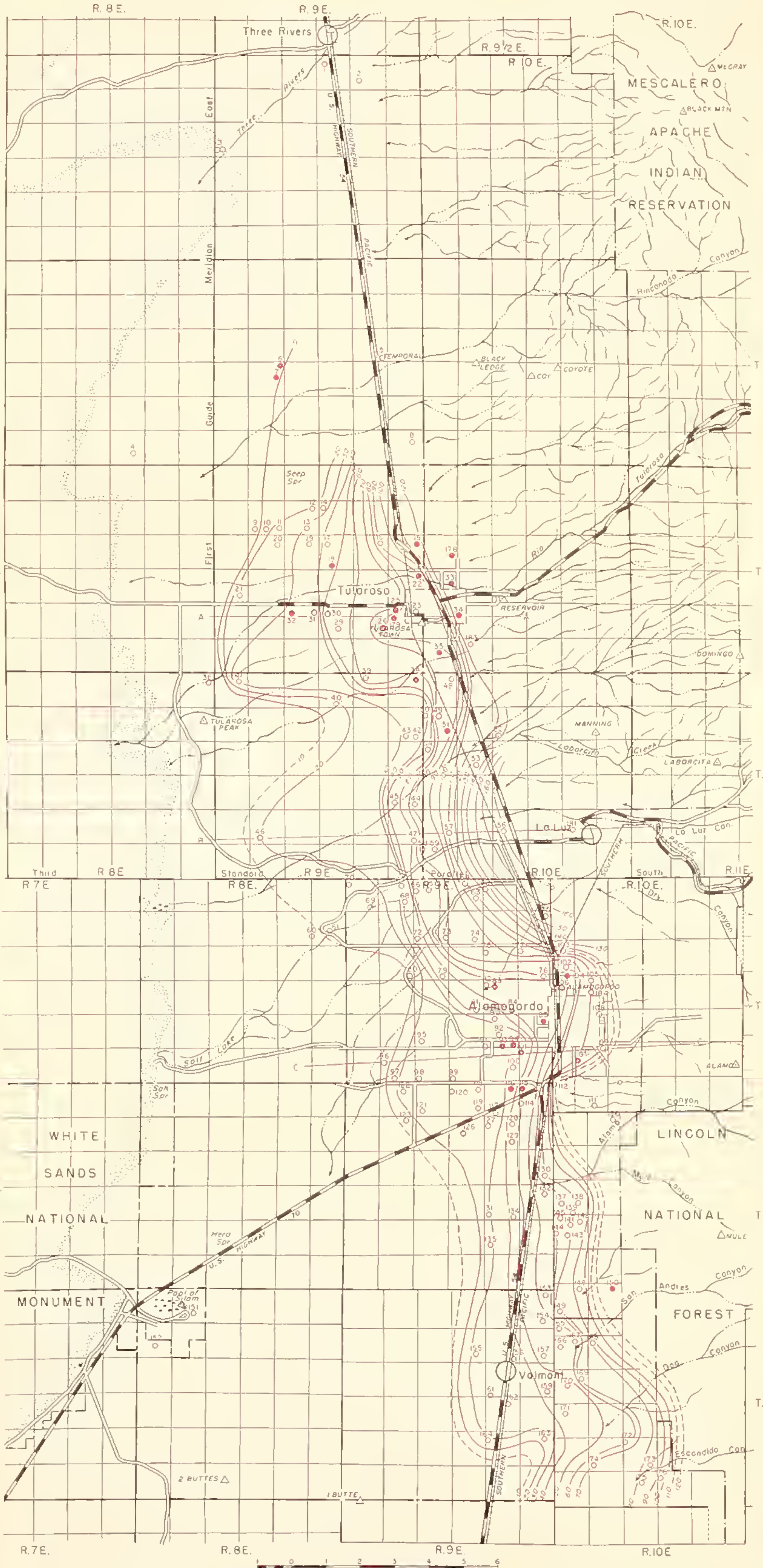


PLATE 2
WELL LOCATIONS
AND
DEPTH TO WATER FROM GROUND SURFACE

LEGEND

45 Stock or Domestic Well

35 Irrigation or Public Supply Well

Number shown is Well Number. For information on Well refer to Table 1

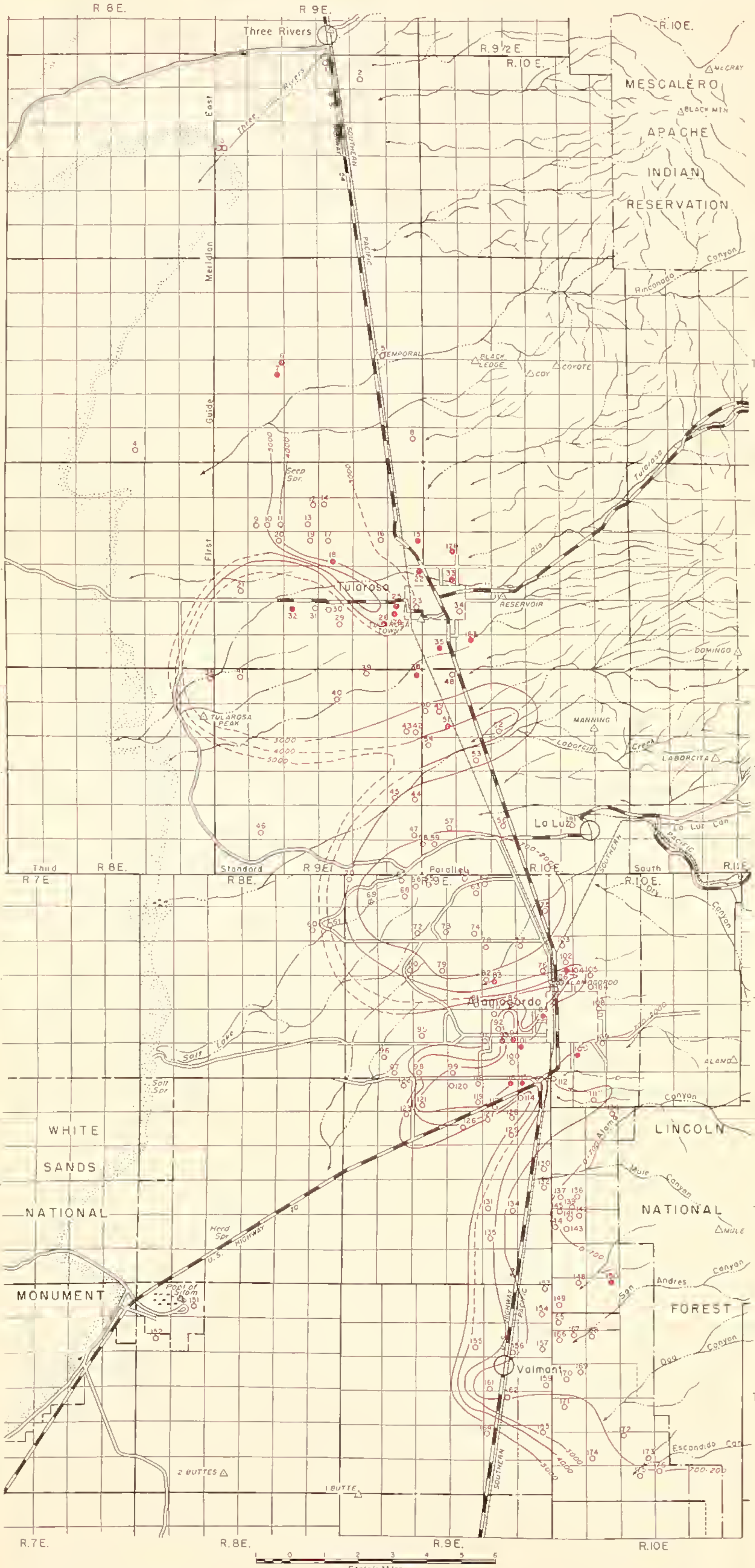
50 Contour line indicating depth to water below ground surface

Contour interval 10'

A—A Cross Section, see Figure 2.

BASE: General Highway Map Otero County, New Mexico

MARCH, 1950



LEGEND

Contour lines indicate concentration of dissolved solids in parts per million

Standards for irrigation water are

Class I less than 700 ppm

Class II 700-2000 ppm

Class III over 2000 ppm

(See text for description of various classes of water)

PLATE 3

QUALITY OF WATER